Exploring Meteorite Mysteries

Lesson 17 —Asteroid Resources:

The Stepping Stone to Beyond

“How can I use them?”

<u>Objectives</u>

Students will:

- actively explore the potential resources available to space travelers through research, assessment, team cooperation, and exploration simulations.
- develop the background to make the connection between meteorite research and potential planetary resources.
- map and core an edible asteroid.

<u>Background</u> — What can we get from an asteroid?

Two types of materials on asteroids appear to be attractive for mining - metals and volatiles. Both of these are essential for space travel. The cost of launching any material from the Earth is extremely high, so useful materials which are already in space can be very valuable.

Most of the asteroids are found in orbits between Mars and Jupiter. However, several hundred have orbits that bring them close to the Earth. Rocket trips to some of these “near-Earth” asteroids would use even less fuel than a trip to the Moon, though the travel time to an asteroid might be much longer.

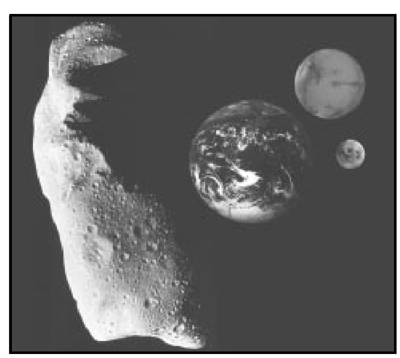
<u>Metals</u> - An asteroid of the composition of an ordinary chondrite could be processed to provide very pure iron and nickel. Valuable byproducts would include cobalt, platinum, gallium, germanium, and gold. These metals are basic to the production of steel and electronic equipment. Some metals from an asteroid mine might even prove valuable enough to be returned to Earth. Iron meteories are high grade ores.

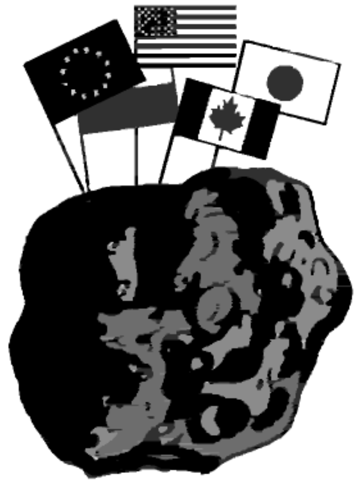
<u>Volatiles</u> - Water, oxygen, and carbon compounds are useful in any space settlement, both for life support and for producing rocket fuel. These volatiles could be found in an asteroid that resembles a carbonaceous chondrite or the nucleus of a former comet. Water contents may range from 5-10% by weight for a chondrite to 60% by weight for a comet nucleus. In some asteroids large quantities of sulfur, chlorine and nitrogen may also be available.

<u>About This Lesson</u>

In teams, students will research and document some of the requirements for mounting an expedition to an asteroid. Activity B allows the students to simulate a miniature mining expedition of an edible asteroid.

(Adapted from “Asteroid Resources” by John S. Lewis in Space Resources, NASA SP-509, Vol. 3, pg. 59-78, 1992)





About This Activity

This is a group-participation simulation based on the premise that water and other resources from the asteroid belt are required for deep space exploration. The class will brainstorm or investigate to identify useful resources, including water, that might be found on an asteroid. Teams of students are asked to take responsibility for planning various aspects of an asteroid prospecting expedition, and to present the results of their planning.

The students should learn that a large project requires the cooperation of many different teams, considering many ideas and needs. Elementary level classes could focus on the simplest aspects of vehicle design, hardware and personnel; advanced level classes could also consider financing for the mission, criteria for crew selection, Earth support teams, training, and maintenance, etc.

Lesson 17 — Asteroid Resources

Activity A: Exploration Proposal

Objectives

Students will:

- plan an expedition or other large engineering project.
- investigate options in many aspects of space flight.
- present their options, reasoning, and recommendations to the group.

Scenario

Time: Sometime in the next century.

Place: Earth.

NASA, in cooperation with national and international space agencies, is planning for human exploration of the outer solar system. The intention is to send expeditions to the moons of Jupiter, Saturn, Uranus, and Neptune to explore, collect samples, and search for clues to the beginnings of the solar system. It is impractical to send all the rocket fuel and consumables (drinking water, air, food) from the Earth because they are heavy, bulky items. Therefore, NASA is looking for sources of rocket fuel and consumables at an intermediate destination, the asteroid belt. Your class has been selected to plan a prospecting expedition to the asteroids to look for resources that could be turned into rocket fuel, drinking water, etc.

Materials for Activity A

❑ resource materials about: space travel, space resources, asteroids, rockets, space shuttle, spacecraft *(see Education Resources, pg. B.2)*
❑ personal log *(journal)*
❑ art supplies
❑ Student Background sheet *(pg. 17.7)*

Procedures

Advanced Preparation

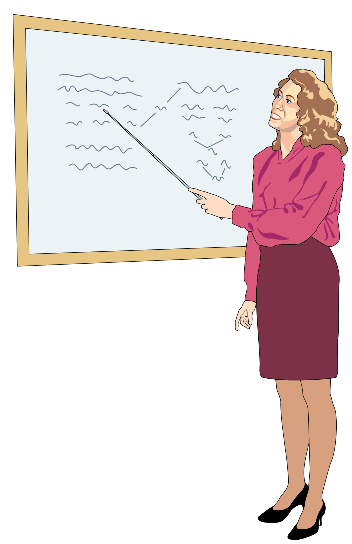
1. Read background material.
2. Assemble research materials or know where students may find them.
3. Copy Student Background sheets as needed.

Classroom Procedure

1. Present background for the problem, and then brainstorm what facts about asteroids might be needed to prepare for a mission that would prospect for water, oxygen, or metals.
2. Brainstorm the important components that must be designed or built to mount a prospecting expedition to an asteroid. Topics to be addressed may vary, depending upon the grade levels of students, availability of information and materials, etc. They could include: propulsion (type of rocket), power, life support, communications, financing (including valuable things that could be mined on an asteroid and returned to Earth), crew selection (including human vs. robotic), ground support, vehicle design, maintenance, prospecting tools, and training.
3. Each team selects a topic from those suggested — all members of the team should reach consensus.
4. Teams will research and document their topic, keeping a log of sources investigated, relevant data found, relevant conversations, meetings, etc. The research should include a "major points" outline, visual aids, references used, and list of possible problems to be resolved through research. Teams should also list "interfaces" with other aspects of the expedition design, (e.g., the electrical power team needs to know how large the crew is, how the life-support system runs, and whether the prospecting tools require electricity).
5. Team results should include the basic questions or trade-offs for their part of the prospecting expedition, advantages and disadvantages for each option (e.g., power from solar cells versus power from a nuclear reactor), and a recommendation of which option is best for the expedition. Groups should present their results to the class.

Questions

1. Why do humans explore?
2. Where does the money for space exploration come from?
3. Might the money be spent better on the many problems on Earth?
4. What are possible economic benefits of space exploration?
5. Might a lunar base be cheaper to run than a space station in low-Earth orbit?
6. What are the advantages/disadvantages of gender-mixed crews?
7. What are the different abilities of human crews and robotic instruments (e.g. compare initiative, adaptability, hardiness, need for life-support)?
8. What types of support teams (on Earth or other home base) are necessary to a mission? Consider human and/or robotic crews.
9. How does destination and crew selection affect vehicle design?
10. What skills/programming would astronauts/robots need during each phase of a mission?
11. Imagine some emergencies that might occur in flight. How might we plan to deal with them? What kinds of problems could not be fixed in a spacecraft millions of miles from home base?



Extensions

1. Create a web showing the interconnections of support personnel necessary to a mission.
2. Research and debate "Human vs. Robotic Exploration."

Lesson 17 — Asteroid Resources

Activity B: Prospecting on Asteroids

About This Activity

This activity allows students to simulate a miniature mining expedition to an edible asteroid.

Materials for Activity B

This will make one large or two small "asteroids" for about 10 students *(groups may take turns)*.

- ❑ 1 large package of chocolate sandwich cookies
- ❑ 10-20 grapes *(depends on size of grapes)*
- ❑ 1 large bag of marshmallows
- ❑ 1 stick of margarine
- ❑ 40 peanuts *(approximate)*
- ❑ 1 large microwaveable bowl
- ❑ 2 containers to hold crushed cookies
- ❑ 1 heavy glass or other object to crush cookies
- ❑ microwave
- ❑ spatula
- ❑ waxed paper
- ❑ refrigerator
- ❑ apple corers, knives, or cork borers
- ❑ toothpicks
- ❑ small tabs for labels
- ❑ Student Worksheet *(pg. 17.8)*
- ❑ metric ruler
- ❑ pens/pencils

Objectives

Students will:

- devise and carry out an investigation plan to prospect for resources on an artificial asteroid.
- use reasoning, observation, and communication skills.
- map an edible asteroid.
- conduct coring or digging excavations to assess and report the "mineral resources" available.

Background

Scientists have found that meteorites contain materials that could be useful to support space travel. Asteroids are the source of many meteorites; therefore, it has been proposed that mines and manufacturing plants on asteroids would be able to supply or replenish needed consumables for deep space expeditions.

<u>Some of the resources include, but are not limited to</u>:

water - found in minerals in carbonaceous chondrites (used for life support or rocket fuel)

diamonds or platinum - found in ureilites (monetary or industrial value)

iron, nickel, cobalt, or gold - found in ordinary chondrites and irons (industrial value)

fine surface materials similar to soils - (for nutrient or plant growth material, insulation, or building blocks)

gallium or germanium - found in ordinary chondrites (used for electronic circuitry)

oxygen - can be extracted from minerals (used for life support and rocket fuel)

carbon - found in carbonaceous chondrites (used for life support and manufacturing)

Procedure

<u>Advanced Preparation</u>

1. If the teacher will be making the "asteroid(s)," allow at least 10 hours of refrigeration before class time (see classroom procedure and recipe on page 17.6).
2. If the class will make the "asteroid(s)," allow two class sessions for this activity.
3. Assemble or assign materials.
4. Review the background material.

Classroom Procedure

Day 1

1. Discuss resources on asteroids; brainstorm the material needs of deep space travelers.
2. Establish and assign tasks (may be based on Activity A or Background Information).
3. Students decide what and why they could prospect on asteroids.
4. Team tasks: make an edible "asteroid", class or team determines what the ingredients represent (see recipe directions below).

Day 2

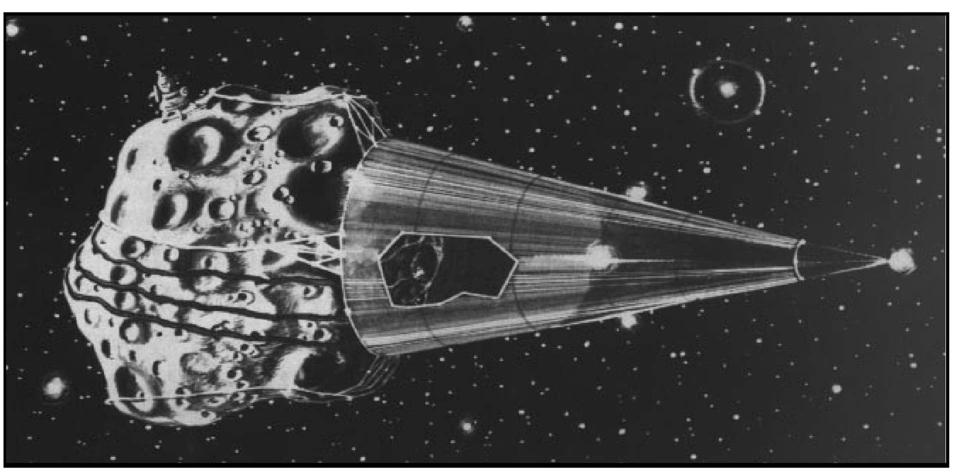
5. Exchange "asteroids" with another team (to make the coring a discovery).
6. Name the "asteroid" (see naming criteria in Lesson 4 — The Meteorite-Asteroid Connection).
7. Draw or map the "asteroid" using the student worksheet; illustrate in detail.
8. Locate the best site for a core sample (a deep cylindrical hole) that will help determine the interior resources.
9. Mark the core location on the map, and on the "asteroid," using a small flag or toothpick.
10. Take one or more core samples using a sharp apple corer or knife.
11. Draw and describe the core on the Student Worksheet, noting the type and amount of "mineral resources" present.
12. Write a brief report to headquarters on Earth, describing the research, findings, and suggestions for further research.

Questions

1. Why would we want to go other places to mine?
2. If the resources of an asteroid are needed to support a deep space exploration mission, where would be a better place from which to launch a resource mining expedition: Earth, a space station, a lunar base, other? Why?

Extensions

1. Create a poster indicating the substances and resources that could be found or produced on different planets, moons, and asteroids. Use information scientists have learned from meteorites and lunar materials.
2. Estimate the cost differences of launching a mining operation from various "jumping off" places.
3. Construct a prototype of a mining facility located on the planetary body of your choice.
4. Set up a booth at a science event to demonstrate your concept for a mining facility.



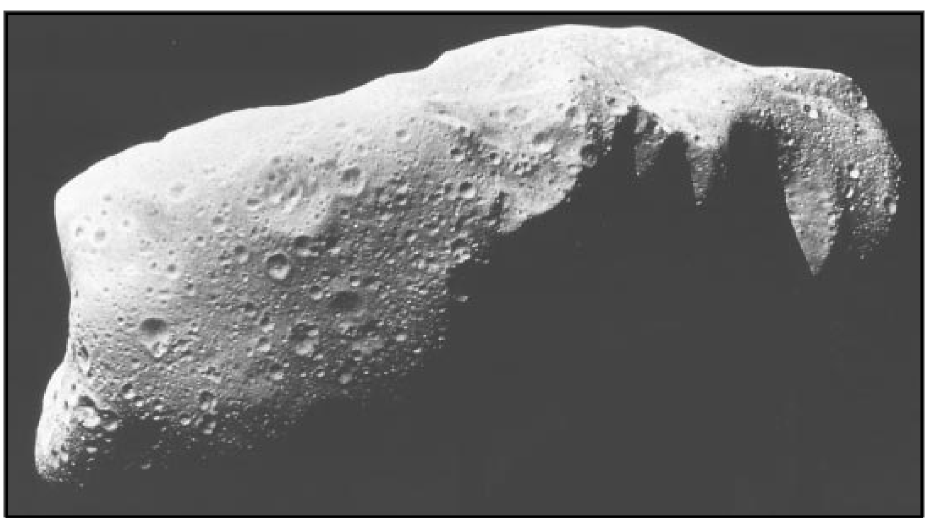
Painting courtesy of Dennis Davidson, American Museum of Natural History, Hayden Planetarium.

Recipe*

See materials list for ingredients

1. Remove filling from approximately 8 cookies, crush cookies into fine particles and set aside on waxed paper for step 7, save filling.
2. Crush remaining cookies (with fillings) into medium-large pieces (add filling from step 1).
3. Mix grapes and peanuts with crushed cookies.
4. Place margarine and marshmallows in microwaveable bowl and melt thoroughly, stir.
5. Combine marshmallow mixture with cookie mixture, blend gently but thoroughly.
6. Using lightly buttered hands, gather the gooey mass into an “asteroid” shape, add “impacts” or “collision fragments” by making indentations in the warm mass.
7. While still warm, roll the “asteroid” in crushed chocolate cookies (this creates a regolith or soil-like surface layer), immediately wrap firmly in waxed paper.
8. Refrigerate overnight.

* *For typical asteroid shape and topography, review the picture of asteroid Ida in the slides and below. This recipe will produce a very dark surface, possibly like a “C” class asteroid, which might correspond to carbonaceous chondrite meteorites.*



Asteroid Ida

Lesson 17 — Asteroid Resources

Student Background: Activity A

Scenario

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Place: Earth.

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Lesson 17 — *Asteroid Resources*

Student Worksheet: Activity B

Prospecting on Asteroids

Group: ____________________ Name: ________________________________

1. Make a drawing or map of the front and back of your asteroid, add appropriate labels. List important materials found in cores. Note the scale (example 1 cm on grid = 3 cm on the asteroid).

3. Draw and label a detailed illustration of the core sample in the space below. The scale may need to be different from the scale above.

4. Write a brief report to headquarters on Earth describing your research. Report findings, especially the type and amount of "mineral resources" present, and suggestions for further exploration or research.